

1 *Sub 77* INTEGRATED TRANSMITTER SURVEYING WHILE  
 2 BORING (SWB) ENTRENCHING POWERING DEVICE  
 3 FOR THE CONTINUATION OF A GUIDED BORE HOLE

4 This application claims the priority of U.S.  
 5 Provisional Application No. 60/174,487, filed January 4,  
 6 2000 and U.S. Provisional Application No. 60/203,040,  
 7 filed May 9, 2000.

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8 BACKGROUND OF THE INVENTION

9 The invention relates to horizontal directional  
 10 drilling and, in particular, to improvements in bottom  
 11 hole assemblies for such drilling techniques.

12 PRIOR ART

13 Horizontal directional drilling methods are well  
 14 known and can offer many advantages over traditional open  
 15 trench digging operations. There remains a need for  
 16 greater precision in monitoring and guiding the course of  
 17 the hole as it is being bored. This need is particularly  
 18 acute in utility easements and like corridors where pre-  
 19 existing lines are located often without precision in  
 20 their placement and "as built" records.

21 As used herein, the terms "sonde" and  
 22 "monitoring/tracking device" are used interchangeably to  
 23 mean a device known in the trenchless boring industry as  
 24 a surveying device for the monitoring and tracking of a  
 25 bore hole. The term "boring device" refers to equipment  
 26 such as a rock tricone drill bit, a poly-diamond-  
 27 crystalline (PDC) bit, or any other device known in the  
 28 art to drill or lengthen a bore hole. Finally, the terms  
 29 "entrenching powering device" and "mud motor" are used  
 30 interchangeably for a device generally known in the art  
 31 used to rotate a boring device, without turning the drill

1 pipe/drill string, by some type of drilling rig to  
2 continue a hole or bore.

3 Known horizontal directional drilling bottom hole  
4 assemblies typically include a sonde that transmits  
5 electromagnetic signals indicating the pitch (from  
6 horizontal), the clock (roll about a horizontal axis  
7 clockwise or counterclockwise from a reference of say 12  
8 o'clock), and the depth of the sonde. The sonde also  
9 enables a person sweeping the corridor with a receiver or  
10 detector to locate the horizontal or lateral position of  
11 the sonde in the specified corridor.

12 Because of limitations of current tooling, the  
13 transmitter/guidance system or sonde is ordinarily  
14 located a considerable distance away from the boring  
15 device when an entrenching powering device is used. The  
16 sonde may only be as close as about 20 feet and as far as  
17 about 50 feet from the boring device. This is due to the  
18 fact that an entrenching powering device has generally  
19 not been designed to integrate a sonde. The distance  
20 between the sonde and the boring device is a major  
21 concern for drillers in the utility business, especially  
22 when they encounter a job with very restrictive  
23 parameters in terms of drilling path.

24 The sonde transmits a signal that indicates where  
25 the sonde is located which can be 20 feet + behind the  
26 boring device. This type of drilling has been described  
27 as driving a car forward, from the back seat looking out  
28 the rear window. A driller only "sees" where he has  
29 already drilled, not where he is currently drilling.  
30 This becomes a major problem if the boring device veers  
31 off course and begins boring outside a designated  
32 corridor. The operator will not know there is a  
33 potential problem until the boring device is 20 feet +  
34 off course. If the driller waits longer to see if the  
35 boring device steers back on course, the boring device

1 may continue even further off course. This causes a risk  
2 that the driller may destroy cable lines, gas lines, or  
3 the like and if such destruction occurs it is not only  
4 expensive but dangerous as well.

#### 5 SUMMARY OF THE INVENTION

6 The invention provides an improved bottom hole  
7 assembly for horizontal directional drilling in which the  
8 sonde is carried ahead of the power section of the  
9 entrenching powering device or mud motor. In a presently  
10 preferred embodiment, the sonde is located in a pocket  
11 formed in the wall of a housing of the entrenching  
12 powering device that surrounds a bearing mandrel or bit  
13 driving shaft. More  
14 specifically, the sonde receiving pocket is nestled  
15 axially between thrust bearings supporting the mandrel  
16 and a flex shaft transmission that couples the power  
17 section to the mandrel. This forward location of the  
18 sonde greatly improves the accuracy of surveying while  
19 boring the hole so as to facilitate placement of the hole  
20 and ultimate line in the intended path.

21 The disclosed mounting arrangement for the sonde  
22 readily allows the sonde to be adjusted for a proper  
23 clock orientation and is somewhat resilient to limit  
24 vibrational forces transmitted to the sonde during  
25 operation.

26 Other mounting structures for the sonde are  
27 disclosed. Each of these structures offers improved  
28 boring accuracy over prior art constructions by enabling  
29 the sonde to be positioned relatively close to the boring  
30 device.

#### 31 BRIEF DESCRIPTION OF THE DRAWINGS

32 FIG. 1 is a side elevational view of a bottom hole  
33 assembly and a portion of a trailing drill string;

1        FIGS. 2A through 2D is a longitudinal cross  
2 sectional view of a mud motor constructed in accordance  
3 with the invention;

4        FIG. 3 is a fragmentary perspective exploded view of  
5 a portion of the mud motor and the sonde;

6        FIG. 4 is a transverse cross sectional view of the  
7 mud motor taken in the plane 4-4 indicated in FIG. 2B;

8        FIG. 5 is a side view, partially in section, of a  
9 second embodiment of the invention; and

10       FIG. 6 is a side view, partially in section, of a  
11 third embodiment of the invention.

#### 12        DESCRIPTION OF THE PREFERRED EMBODIMENTS

13       With reference particularly to FIGS. 1, 2A - 2D, 5  
14 and 6, parts towards the left are sometimes hereafter  
15 referred to as forward parts in the sense of the drilling  
16 direction, it being understood that in such figures, the  
17 drilling direction is to the left; the rearward or  
18 trailing end of such parts, conversely, is shown to the  
19 right. The forward direction can be equated with a  
20 downward direction and the rearward direction can be  
21 equated with an upper direction where drilling is  
22 vertical.

23       Referring now to FIG. 1, a bottom hole assembly 10  
24 comprises a boring device or bit 11 and an entrenching  
25 powering device or mud motor 12 having its forward end  
26 carrying the bit 11. A drill string 13 is coupled to a  
27 trailing end 14 of the mud motor 12 in a conventional  
28 fashion.

29       The mud motor 12, as shown in FIGS. 2A - 2D includes  
30 a hollow cylindrical bearing mandrel 18 having a central  
31 through bore 19. The bit 11 is coupled to a bit box 21  
32 formed in the forward end of the bearing mandrel 18.  
33 Thus, the bearing mandrel 18 is enabled to drive the bit

1 11 in rotation and to transmit thrust from the drill  
2 string 13.

3 Adjacent its forward end 22, the bearing mandrel 18  
4 is rotationally supported in a lower tubular cylindrical  
5 housing 23 by a set of radial bearings 24. A conical  
6 shoulder 28 of the bearing mandrel 18 is received in a  
7 conical bore 29 of a radial ring 31. A radial face of  
8 the ring 31 is arranged to abut an adjacent one of the  
9 set of radial bearings 24. Male threads 36 of the lower  
10 or forward housing 23 couple with female threads 38 in a  
11 forward end 39 of an elongated hollow circular outer  
12 housing 41.

13 Sets of thrust bearings 44, 46 are assembled on a  
14 carrier nut 47 at opposite sides of an annular flange 48.  
15 The carrier nut 47 is threaded onto an externally  
16 threaded part 49 of the bearing mandrel 18. The carrier  
17 nut 47 is locked in position on the bearing mandrel 18 by  
18 set screws 51 spaced about the periphery of the flange  
19 48.

20 Sleeve bearings 53, of suitable self-lubricating  
21 material such as the material marketed under the  
22 registered trademark DU® are received in counterbores 54  
23 formed in the outer housing 41 and serve to rotationally  
24 support the mid and trailing length of the bearing  
25 mandrel 18. A longitudinal bore 56 in the surrounding  
26 outer housing 41 provides clearance for the main length  
27 of the bearing mandrel 18.

28 An annular piston 59 floats on a rearward part of  
29 the mandrel 18 in a counterbore 61 in the outer housing  
30 41. The piston 59 retains lubricant in the annular zones  
31 of the bearings 53, 44 and 46. A circular bearing  
32 adapter 62 is threaded onto the rear end of the bearing  
33 mandrel 18. A plurality of holes 63 distributed about  
34 the circumference of the adapter 62 are angularly drilled  
35 or otherwise formed in the adapter to provide mud flow

1 from its exterior to a central bore 64 of the adapter.  
2 As shown, the central bore 64 communicates directly with  
3 the bore 19 of the bearing mandrel 18. The bearing  
4 adapter 62 is radially supported for rotation in a  
5 sleeve-type marine bearing 66 assembled in a counter bore  
6 67 in a rear portion of the outer housing 41. Ports 68  
7 allow flow of mud through the marine bearing 66 for  
8 cooling purposes.

9 A flex shaft 71 rotationally couples a rotor adapter  
10 72 to the bearing adapter 62. At each end of the flex  
11 shaft 71 is a constant velocity universal joint 73  
12 comprising a series of circumferentially spaced balls 74  
13 seated in dimples in the flex shaft and in axially  
14 extending grooves in a skirt portion 76 of the bearing  
15 adapter 62 or skirt portion 77 of the rotor adapter 72.  
16 Each coupling or universal joint 73 also includes a ball  
17 78 on the axis of the flex shaft and a ball seat 79  
18 received in the respective bearing adapter 62 or rotor  
19 adapter 72. Each universal joint 73 includes a bonnet 81  
20 threaded into each of the skirts 76 or 77 to retain the  
21 joints or couplings 73 in assembly. Cylindrical  
22 elastomeric sleeves 82 are disposed within each of the  
23 bonnets 81 to retain grease in the area of the balls 74,  
24 78 and to exclude contamination from this area. A  
25 cylindrical tubular flex housing 84 surrounds the flex  
26 shaft 71 and is fixed to the rear end of the outer  
27 housing 41 by threading it into the latter at a joint 86.  
28 The flex housing 84 is bent at a mid plane 87 such that  
29 the central axis at its rear end is out of alignment with  
30 its central axis at its forward end by a small angle of,  
31 for example, 2°. At its rearward end, the flex housing 84  
32 is fixed to the stator or housing 88 of a power section  
33 89 of the mud motor 12 by a threaded joint 91. The  
34 stator 88 is a hollow internally fluted member in which  
35 operates an externally fluted rotor 92. The power

1 section 89 formed by the stator 88 and rotor 92 are of  
2 generally known construction and operation. The rotor  
3 adapter 72 is threaded into the forward end of the rotor  
4 92 to rotationally couple these members together. The  
5 drill string 13 is threaded on the rear end of the stator  
6 with or without the use of an adapter. The flex shaft 71  
7 converts the rotational and orbital motion of the rotor  
8 92 into plain rotation of the bearing mandrel 18.

9 Referring particularly to FIGS. 3 and 4, the outer  
10 housing 41 is formed with a pocket or elongated recess  
11 101 rearward of the thrust bearing units 44, 46. The  
12 pocket 101 is milled or otherwise cut out of the wall of  
13 the outer housing 41 with an included angle of 90° in the  
14 plane of FIG. 4 transverse to the longitudinal axis of  
15 the housing 41. Surrounding the pocket 101 is a  
16 relatively shallow seat or recess 102 similarly cut into  
17 the wall of the housing 41. When viewed in the plane of  
18 FIG. 4, this seat has a cylindrical arcuate surface area  
19 103 concentric with the axis of the housing 41 and  
20 radially extending surfaces 104.

21 An elastomeric sarcophagus 106 of polyurethane or  
22 other suitable material has exterior surfaces generally  
23 conforming to the surfaces of the pocket 101. The  
24 sarcophagus 106 is configured with a round bottom slot  
25 107 for receiving a sonde 108. More specifically, the  
26 slot 107 is proportioned to receive a standard  
27 commercially available sonde of a size which, for  
28 example, can be 1-1/4" diameter by 19" long. It is  
29 understood that the sarcophagus may be configured with a  
30 slot to fit sondes of other standard sizes such as 1"  
31 diameter by 8" long or a secondary sarcophagus may be  
32 provided to increase the effective size of a smaller  
33 sonde to that of the larger size. An arcuate cover plate  
34 109 of steel or other suitable material is proportioned  
35 to fit into the area of the seat 102 to cover and

1 otherwise protect the sonde 108 from damage during  
2 drilling operations. The cover 109 is proportioned, when  
3 installed in the seat 102, to provide an outer  
4 cylindrical surface 111 that lies on the same radius as  
5 that of the outer cylindrical surface of the housing 41  
6 surrounding the pocket or slot 101. The cover 109, is  
7 provided with a plurality of longitudinal through slots  
8 112, to allow passage of electromagnetic signals  
9 transmitted from the sonde 108. The slots 112 are filled  
10 with non-metallic material such as epoxy to exclude  
11 contaminants from passing into the pocket 101 or  
12 otherwise reaching the sonde 108. Additionally, for  
13 purposes of allowing the sonde to transmit signals over a  
14 wide angle, the body of the housing 41 is drilled with  
15 holes 113 which are filled with epoxy or other non-  
16 metallic sealant. A shallow groove 114 is cut in a  
17 generally rectangular pattern in the surface 103 around  
18 the pocket 101 to receive an O-ring seal 116.

19 The round bottom slot or groove 107 in the  
20 sarcophagus is dimensioned to provide a friction fit with  
21 the sonde 108. This permits the sonde 108 to be rotated  
22 or rolled on its longitudinal axis to "clock" it by  
23 registering its angular orientation relative to the plane  
24 of the bend in the flex housing 84 as is known in the  
25 art.

26 The cover or plate 109 is retained in position over  
27 the sonde 108 by a plurality of screws 117 assembled  
28 through holes 118 in the cover and aligned with threaded  
29 holes 119 formed in the outer housing 41. The screw  
30 holes 118, 119 are distributed around the periphery of  
31 the cover 109. The O-ring 116 seals against the inside  
32 surface of the cover 109 to exclude contaminants from  
33 entering the pocket 101 during drilling operations.

34 The sarcophagus 106 is proportioned so that it is  
35 compressed by the cover 109 around the sonde 108 when the



1 screws 117 draw the cover tight against the seat surface  
2 103. This compression of the sarcophagus 106 increases  
3 its grip on the sonde 108 so that the sonde is locked in  
4 its adjusted "clocked" position. The elastomeric  
5 property of the sarcophagus 106, besides enabling it to  
6 resiliently grip the sonde when compressed by the cover  
7 109, can serve to cushion the sonde 108 from excessive  
8 shock forces during drilling operation.

9 Other resilient mounting structures for the sonde  
10 108 are contemplated. For example, the sonde 108 can be  
11 retained in the pocket 101 by resilient steel straps  
12 arranged to overlies the sonde as it lies in the pocket  
13 101. The straps can be retained in place by suitable  
14 screws or other elements.

15 When the mud motor 12 is operated, mud or water  
16 passing between the stator 88 and rotor 92 travels  
17 through the transmission and bearing sections of the mud  
18 motor bounded by the flex housing 84, outer housing 41,  
19 and lower housing 23 and is delivered to the bit 11.  
20 More specifically, the mud flows through the annulus  
21 between the flex shaft 71 and an inner bore 120 of the  
22 flex housing 84. From this annulus, the mud enters the  
23 central bore 64 of the bearing adapter through the  
24 angularly drilled holes 63. The mud flows from this bore  
25 64 through the axial bore 19 in the bearing mandrel 18.

26 From the foregoing description, it can be seen that  
27 the disclosed arrangement in which the sonde is received  
28 in the wall of a main housing part, namely the outer  
29 housing 41, the sonde can be disposed quite close to the  
30 bit 11 with minimal hardware and without complexity. As  
31 seen, the flow of mud from the power section 89 to the  
32 bit 11 is unrestricted and the diameter of the  
33 transmission section is not unnecessarily enlarged beyond  
34 that which is already required for the necessary bearings  
35 and other componentry. By locating the sonde 108 close

1 to the bit 11, much greater accuracy in monitoring and  
2 tracking the progress of the boring process over that  
3 possible with the prior art is achieved.

4 Operation of the mud motor to steer the pipe string  
5 along its desired path will be evident to those skilled  
6 in the art. Typically, to adjust the direction of the  
7 bore, the drill string is rotated to point the bit in the  
8 direction of the needed adjustment. The orientation of  
9 the bit is transmitted to a surface receiver by the  
10 sonde. The drill string is held against rotation while  
11 the mud motor rotates the bit and the drill string is  
12 thrust forward to redirect the direction of the bore.  
13 The disclosed mud motor provides a unique function that  
14 is enabled by the provision of the forward set of thrust  
15 bearings 44. These bearings 44 allow the mud motor to  
16 operate to rotate the bit 11 when the drill string is  
17 being pulled out of the hole so that during this  
18 withdrawal process the hole is conveniently reamed or  
19 enlarged with a hole opening device.

20 FIGS. 5 and 6 illustrate additional embodiments of  
21 the invention. Parts like those described in connection  
22 with the embodiment of FIGS. 1 - 4 are designated with  
23 the same numerals. In FIG. 5, a tubular cylindrical  
24 collar 126 housing the sonde 108 is assembled around a  
25 housing 127 that corresponds to the outer housing 41 of  
26 the embodiment of FIGS. 1 - 4. The collar 126 is formed  
27 of steel or other suitable material. The collar 126 is  
28 fixed longitudinally and angularly relative to the  
29 housing 127 by set screws 128 threaded into the wall of  
30 the collar 126 and received in blind holes 129 drilled in  
31 the wall of the housing 127. The sonde 108 is received  
32 in the sarcophagus 106 and protected by the cover 109 as  
33 previously described. Various other techniques, besides  
34 the set screws 128, can be used to fix the collar 126 on  
35 the housing 127. The collar 127 can be threaded onto the

1 housing 127 where the housing, for example, is provided  
2 with external threads and a stop shoulder. Another  
3 technique is to weld the collar 126 to the housing 127.  
4 If desired or necessary, the sonde 108 can be assembled  
5 in a hole aligned with the axis of the collar 126 and  
6 open at one end. The opening can be plugged with a  
7 suitable closure during use.

8 FIG. 6 illustrates another embodiment of the  
9 invention. A coupler 131 is disposed between the bearing  
10 mandrel 18 and the bit 11. The coupler 131 has external  
11 threads mated with the bit box 21 and internal threads  
12 receiving the bit 11. The coupler 131 is formed with the  
13 pocket 101 for receiving the sonde 108. The coupler 131  
14 has a central bore for conveying mud from the bearing  
15 mandrel 18 to the bit 11. If desired, an axially  
16 oriented hole can be used instead of the open face pocket  
17 101 to receive the sonde 108 and the hole can be plugged  
18 by a suitable closure. Still further, if it is desired  
19 to locate the sonde 108 at the center of the coupler 131,  
20 water corsets or passages can be drilled or otherwise  
21 formed axially through the coupler and circumferentially  
22 spaced about the sonde to allow mud to pass through the  
23 coupler.

24 While the invention has been shown and described  
25 with respect to particular embodiments thereof, this is  
26 for the purpose of illustration rather than limitation,  
27 and other variations and modifications of the specific  
28 embodiments herein shown and described will be apparent  
29 to those skilled in the art all within the intended  
30 spirit and scope of the invention. Accordingly, the  
31 patent is not to be limited in scope and effect to the  
32 specific embodiments herein shown and described nor in  
33 any other way that is inconsistent with the extent to  
34 which the progress in the art has been advanced by the  
35 invention.